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ABSTRACT

Test items relating to Project Physics Unit 2 are presented in this booklet. Included are 70 multiple-choice and 22 problem-and-essay questions. Concepts of motion in the heavens are examined for planetary motions, heliocentric theory, forces exerted on the planets, Kepler's laws, gravitational force, Galileo's work, satellite orbits, Jupiter's moons, Tycho's observations, stellar parallax, and historical descriptions in astronomy. Suggestions are made for time consumption in answering some items. Besides directions and illustrations for explanation purposes, related physical constants and equations are provided. The work of Harvard Project Physics has been financially supported by: the Carnegie Corporation of New York, the Ford Foundation, the National Science Foundation, the Alfred P. Sloan Foundation, the United States Office of Education, and Harvard University. (CC)

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Project Physics **Tests** 2

An Introduction to Physics

Motion in the Heavens

SE 015 525

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This test is the authorized interim version of one of the many instructional materials being developed by Harvard Project Physics, including text units, laboratory experiments, and teacher guides. Its development has profited from the help of many of the colleagues listed at the front of the text units.

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Directions

This test consists of fifteen multiple-choice questions and seven problem-and-essay questions, divided into two groups. Answer ALL multiple-choice questions by marking the letter corresponding to the one best answer. Answer THREE of the problem-and-essay questions from Group One and ONE from Group Two. Spend about 15 minutes on the multiple-choice questions, 5 minutes on each of the problem-and-essay questions from Group One and 10 minutes on the problem-and-essay question from Group Two.

NOTE:
The numerical values of some physical constants and equations that may be useful in the test are given below.

Physical Constant:

Acceleration of gravity on surface of earth (approximate value to be used in this test) $a_g = 10$ meters/sec^2

Radius of the earth $R_E = 6{,}000{,}000$ meters

Mass of the earth $m_E = 5.96 \times 10^{24}$ kg

Equations:

$$F_{grav} = G\frac{m_1 m_2}{R^2} \qquad v = \frac{2\pi R}{T}$$

$$T^2 = ka^3 \qquad a = \frac{v^2}{R}$$

$$T^2 = \left[\frac{4\pi^2}{Gm}\right] R^3 \qquad \frac{m_1}{m_2} = \left[\frac{R_1}{R_2}\right]^3 \left[\frac{T_2}{T_1}\right]^2$$

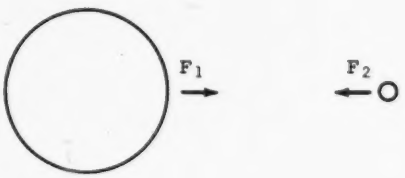
1. To ancient observers, the principal difference between the planets and the stars was that the planets appeared

A. brighter.
B. more like the earth.
C. to wander among the other stars.
D. closer to the earth.
E. to travel around the sun.

2. Which of the following statements must be part of any heliocentric theory?

A. The planets revolve around the sun.
B. The sun is a sphere.
C. The earth is a sphere.
D. The planets revolve around the earth.
E. The earth turns on its axis.

3. If F_1 is the magnitude of the force exerted on the sun by the earth and F_2 is the magnitude of the force exerted on the earth by the sun, then



A. F_1 is much greater than F_2.
B. F_1 is slightly greater than F_2.
C. F_1 is equal to F_2.
D. F_1 is slightly less than F_2.
E. F_1 is much less than F_2.

4. Which one of the following men is famous for the decision to abandon Plato's association of heavenly bodies with "uniform motion in perfect circles?"

A. Aristotle
B. Copernicus
C. Kepler
D. Galileo
E. Tycho Brahe

5. Galileo accumulated a great deal of evidence which was inconsistent with the medieval view of the universe. ALL EXCEPT ONE of the following are examples of this evidence. Which is the exception?

A. the discovery of a new star in 1604
B. the rough appearance of the moon's surface
C. the motion of four luminous objects around Jupiter
D. the moon-like phases of planet Venus
E. the wanderings of the planets among the stars

6. Two sacks of marbles are hung one meter apart. Which of the following would approximately double the gravitational force that one sack of marbles exerts on the other sack?

A. Double the number of marbles in one sack.
B. Double the number of marbles in both sacks.
C. Move them closer, to one-half the separation.
D. Move them further apart, to twice the separation.
E. Move them further apart, to four times the separation.

7. ALL EXCEPT ONE of the following statements are acceptable. Which is the exception?

A. The earth is moving fastest when closest to the sun.
B. The path of the earth lies in a plane which passes through the sun.
C. A line drawn from the sun to the earth sweeps over the same area from March 21 to March 23 as it does from December 21 to December 23.
D. The sun is at the exact center of the earth's path.

8. Assume that the earth suddenly shrank to one-half its original diameter, but that its mass remained unchanged. Under these circumstances, the weight of a person standing on its surface would be

A. four times as great.
B. twice as great.
C. the same.
D. one-half as great.
E. one-fourth as great.

9. A friend tells you the earth is fixed in space and that the sun revolves about it. Which one of the following facts contradicts his hypothesis?

A. Each day the sun rises in the east and sets in the west.
B. During the night the stars appear to move.
C. The sun makes one complete trip among the stars in one year.
D. Eclipses of the sun sometimes occur.
E. none of the above

10. Which one of the following was an important factor that worked against the acceptance of Copernicus' heliocentric solar system hypothesis in the sixteenth century?

A. When Venus was observed through a telescope, phases were seen.
B. Stellar parallax had never been observed.
C. The calendar failed to keep pace with the seasons.
D. Galileo observed four satellites moving around Jupiter.
E. Venus had never been observed more than 48° from the sun.

11. ALL EXCEPT ONE of the following were among Tycho Brahe's contributions to astronomy. Which one is the exception?

A. He established an astronomical observatory.
B. He proposed an inverse square law of attraction for the solar system.
C. He developed a theory of the solar system.
D. He determined the limits of accuracy of his instruments.
E. He made very accurate observations of the positions of the heavenly bodies.

12. Assume that the following measurements were made on three planets revolving about a star. (Planets listed in order of discovery)

Planet	Orbital Period	Mass
Alpha	14 earth years	10 earth masses
Beta	188 earth years	17 earth masses
Gamma	50 earth years	1/2 earth mass

On the basis of Kepler's laws of planetary motion, these planets could be arranged in order of their increasing distance from the star. If the planets were listed in sequence, starting with the planet nearest the star, they would be arranged

A. Alpha, Beta, Gamma.
B. Beta, Gamma, Alpha.
C. Gamma, Alpha, Beta.
D. Beta, Alpha, Gamma.
E. Alpha, Gamma, Beta.

13. The following men made significant contributions to our present understanding of planetary motion:

1. Copernicus
2. Newton
3. Kepler

If the names of these men were arranged in the order of their contributions starting with the earliest first, they would be

A. 1, 2, 3
B. 2, 3, 1
C. 3, 1, 2
D. 1, 3, 2
E. 2, 1, 3

14. Time-exposure photographs of stars show arcs of circles. An astronomer who believed the Ptolemaic theory of planetary motion would explain that these arcs result from

A. the rotation of the earth on its axis.
B. stellar parallax.
C. retrograde motion.
D. the inclination of the earth's axis.
E. the rotation of the starry sphere.

15. Which one of the following is evidence that supports the universality of Newton's law of gravitation?

A. Pairs of stars have been observed that move around each other in accordance with Kepler's laws.
B. A few stars have moved from the positions given for them in Ptolemy's catalogue of stars.
C. Stellar parallax has been observed for several thousand stars.
D. A calendar reform was needed in the sixteenth century to keep months and seasons in agreement.

Test A

PROBLEM-AND-ESSAY QUESTIONS

Group One

Answer THREE of the following five questions.

1. Indicate briefly the major contributions to astronomy of

   a) Ptolemy
   b) Copernicus

2. With the aid of a diagram, briefly describe the experiment used by H. Cavendish to determine the value of G, the constant of universal gravitation in the equation

$$F_{grav} = G \frac{m_1 m_2}{R^2} .$$

3. The orbit of Mercury about the sun has a radius about 1/3 that of the orbit of the earth about the sun, while the period of Mercury is about 3 months. With the aid of a diagram of a heliocentric (sun-centered) system explain the retrograde motion of Mercury as seen from the earth.

4. According to the theory of relativity, nature may be validly observed and described from all frames of reference. Why then have astronomers, in describing the motions of planets, preferred a heliocentric rather than a geocentric frame of reference?

5. Describe the daily and annual motion of the sun from a geocentric point of view.

Group Two

Answer ONE of the following two questions.

6. According to Newton, the moon is continually falling toward the earth. In what sense is the word "falling" used here? Explain your answer by linking the motion of the moon with the motion of a freely falling object near the surface of the earth.

7. Given Newton's assumption for the gravitational force due to the sun on a planet: $F \propto 1/R^2$, and given that the distance of fall of a planet is determined by $d = \frac{1}{2} at^2$, derive Kepler's third law in the form

$$\frac{(T_s)^2}{(T_p)^2} = \frac{(R_s)^3}{(R_p)^3} .$$

Directions

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NOTE:
The numerical values of some physical constants and equations that may be useful in this test are given below.

Physical Constants:

Acceleration of gravity on surface of earth (approximate value to be used in this test) $a_g = 10$ meters/sec^2

Radius of the earth $R_E = 6{,}400{,}000$ meters

Mass of the earth $m_E = 5.96 \times 10^{24}$ kg

Equations:

$$F_{grav} = G\frac{m_1 m_2}{R^2} \qquad v = \frac{2\pi R}{T}$$

$$T^2 = ka^3 \qquad a = \frac{v^2}{R}$$

$$T^2 = \left[\frac{4\pi^2}{Gm}\right] R^3 \qquad \frac{m_1}{m_2} = \left[\frac{R_1}{R_1}\right]^3 \left[\frac{T_2}{T_1}\right]^2$$

TEST B

1. In its orbit, the earth travels

A. fastest when it is nearest the sun.
B. fastest at night.
C. fastest around the time of the new moon.
D. with constant speed.

Select answers to questions 2 and 3 from the following list.

A. Ptolemy
B. Kepler
C. Copernicus
D. Tycho Brahe
E. Galileo

2. He tried to relate planetary distances to the five regular geometric solids.

3. He developed a model of the solar system in which the planets revolved around the sun but the earth remained motionless.

4. ALL EXCEPT ONE of the following are characteristics of geocentric models of the solar system. Which one is the exception?

A. The earth is at or near the center of the solar system.
B. The stars are at the greatest distance from the earth.
C. The sun moves daily around the earth.
D. The moon's motion is tied to the motion of the sun.
E. The stars move daily around the earth.

5. Kepler's three laws of planetary motion were

A. almost self-evident from Tycho Brahe's data of Mars' orbit.
B. little used in Newton's development of a general law of universal gravitation.
C. developed only after Kepler took imaginative steps from the available data.
D. widely discussed early in the seventeenth century.
E. used by Copernicus in deriving his heliocentric hypothesis.

6. Tycho Brahe's most important contribution to science was

A. the accurate observation of the positions of the stars and planets.
B. the discovery of a new star that changed its brightness.
C. the discovery of elliptical orbits.
D. his theory of planetary motions.

7. Galileo accumulated a great deal of evidence which was inconsistent with the medieval view of the universe. ALL EXCEPT ONE of the following are examples of this evidence. Which is the exception?

A. the discovery of a new star in 1604
B. the rough appearance of the moon's surface
C. the motion of four luminous objects around Jupiter
D. the moon-like phases of planet Venus
E. the wanderings of the planets among the stars

8. A satellite with a television camera is placed in an orbit 24,000 miles above the earth so that it remains exactly above the same point on earth at all times, with its camera pointed toward the earth. As seen from the sun the orbit of the satellite is

A. an ellipse with the sun at one focus.
B. an epicycle with its center on the orbit of the sun.
C. an epicycle with its center on the orbit of the earth.
D. a circle with the sun at the center.
E. a parabola constantly accelerated toward the earth.

9. Assume the earth suddenly became one-half its original diameter, but that its mass was unchanged. Under this assumption, the strength of the earth's gravitational pull on the moon would be

A. four times as great.
B. twice as great.
C. the same.
D. one-half as great.
E. one-fourth as great.

10. What is the acceleration due to gravity of a meteor at 2 earth radii from the center of the earth? Assume the acceleration due to gravity at one earth radius from the center of the earth to be 10 $\frac{\text{meters}}{\text{second}^2}$.

A. 2.5 m/sec^2
B. 5 m/sec^2
C. 7.07 m/sec^2
D. 10 m/sec^2
E. 20 m/sec^2

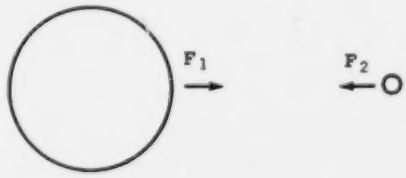
11. Which one of the following is evidence that supports the universality of Newton's law of gravitation?

A. A few stars have moved from the positions given for them in Ptolemy's catalogue of stars.
B. Stellar parallax has been observed for several thousand stars.
C. Eclipses of the sun do not occur at every new moon.
D. A calendar reform was needed in the sixteenth century to keep months and seasons in agreement.
E. Pairs of stars have been observed that move around each other in accordance with Kepler's laws.

12. If a theory predicts a result which is contrary to common sense, we should

A. reject the theory since we must rely on common sense.
B. devise an experiment to test the predicted result.
C. disregard common sense because it is of no value in a scientific study.
D. revise the theory to produce a compromise between the theory and common sense.

13. If F_1 is the magnitude of the force exerted on the sun by the earth and F_2 is the magnitude of the force exerted on the earth by the sun, then



A. F_1 is much greater than F_2.
B. F_1 is slightly greater than F_2.
C. F_1 is equal to F_2.
D. F_1 is slightly less than F_2.
E. F_1 is much less than F_2.

14. In describing the motion of a thrown rock, Newtonian physics introduced a premise which was <u>not</u> part of Aristotelian physics. Which of the following is the Newtonian premise?

A. A force is needed to change the state of the rock from rest to motion.
B. The rock has no properties that affect its motion.
C. The undisturbed motion of the rock is uniform motion along a straight line.
D. The natural state of the rock is rest.

15. Galileo's discovery of Jupiter's moons provided supporting evidence for

A. Aristotle's solution to Plato's problem.
B. the Copernican theory of planetary motion.
C. the existence of epicycles.
D. the geocentric hypothesis of Ptolemy.
D. the accuracy of Tycho Brahe's observations.

PROBLEM-AND-ESSAY QUESTIONS

Group One

Answer THREE of the following five questions.

1. Describe the annual motion of the sun against the background of the stars as observed from the earth.

2. Describe the role played by stellar parallax in the arguments for and against a heliocentric theory of the universe.

3. Describe the relationship between Newton's law of gravitation $F_{grav} = G \frac{m_1 m_2}{R^2}$ and Galileo's observation that the gravitational acceleration at the surface of the earth is the same for all falling bodies.

4. The scientific theories of Galileo and Copernicus were severely criticized by some of their contemporaries. Were they criticized on scientific grounds? Explain your answer.

5. If two planets A and B have the same mass but the radius of A is twice that of B,

   a) which planet has the greater gravitational pull at its surface?
   b) what is the ratio of the surface gravitational pulls of the two planets?

Group Two

Answer ONE of the two questions in this group.

6. The text indicates that Galileo, Kepler and Newton each made contributions that helped change man's scientific outlook from an Aristotelian to a modern point of view. Pick two of these men and describe briefly their contributions in producing this changed outlook.

7. Two criteria for an adequate theory are:

   1. that it be based upon simple assumptions.
   2. that it be in agreement with experimental observations.

Consider the sun-centered system of planetary motion published by Copernicus in 1543 A.D.

   a) Did it satisfy these criteria?
   b) Did it satisfy them better than the older Ptolemaic (earth-centered) system? Explain your answer.

Directions:

Answer ALL 40 multiple-choice questions by marking the letter corresponding to the one best answer.

NOTE:
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$$T^2 = \left[\frac{4\pi^2}{Gm}\right] R^3 \qquad \frac{m_1}{m_2} = \left[\frac{R_1}{R_2}\right]^3 \left[\frac{T_2}{T_1}\right]^2$$

Test C

1. Which of the following s statements must be part of any heliocentric theory?

A. The planets revolve aroun und the sun.
B. The sun is a sphere.
C. The earth is a sphere.
D. The planets revolve aroun und the earth.
E. The earth turns on its ax axis.

2. Time exposure photograph phs of stars show an arc of a circle for each star. An astronomer who believed the e Ptolemaic theory of planetary motion would explain that these arcs result from

A. the rotation of the earth th on its axis.
B. stellar parallax.
C. retrograde motion.
D. the inclination of the ea earth's axis.
E. the rotation of the starr irry sphere.

3. Which of the following w was an important factor that worked against the acceptance of Copernicus' helic liocentric solar system hypothesis in the sixteenth century?

A. When Venus was observed t through a telescope, phases were seen.
B. The calendar failed to ke keep pace with the seasons.
C. Galileo observed four sat satellites moving around Jupiter.
D. Venus had never been obse served more than 48° from the sun.
E. Stellar parallax had neve ver been observed.

4. Galileo's discovery of J Jupiter's moons provided supporting evidence for

A. Aristotle's solution to P Plato's problem.
B. the Copernican theory of f planetary motion.
C. the existence of epicycl les.
D. the geocentric hypothesis ia of Ptolemy.
E. the accuracy of Tycho Br rahe's observations.

5. To ancient astronomers, , planets were different from stars because planets

A. moved in circles.
B. were unlike the earth in n composition.
C. moved against the backgr round of stars.
D. moved around the sun.
E. were within the sphere o of the sun.

6. Which of the following led to a numerical value of the constant G in the equation

$$F_{grav} = G \frac{m_1 m_2}{R^2} \quad ?$$

A. calculations of the moon's orbit by Tycho Brahe
B. a laboratory experiment by Cavendish
C. observations of Jupiter's moons by Galileo
D. an experiment with balls rolling down an incline by Galileo
E. calculations of the orbit of Mars by Kepler

7. ALL EXCEPT ONE of the following are objections which were raised against the heliocentric model of the solar system. Which one is the exception?

A. It failed to fit the observations.
B. It displaced man from his unique position in the center of the universe.
C. It was contrary to common sense which demonstrates that the earth is motionless.
D. It failed to distinguish between base terrestrial matter and heavenly matter.
E. It conflicted with Aristotelian physics.

8. ALL EXCEPT ONE of the following were among Tycho Brahe's contributions to astronomy. Which one is the exception?

A. He established an astronomical observatory.
B. He proposed an inverse square law of attraction for the solar system.
C. He developed a theory of the solar system.
D. He determined the limits of accuracy of his instruments.
E. He made very accurate observations of the positions of the heavenly bodies.

9. Which of the following correctly places the earth, Jupiter, Mars, the moon and sun in order of increasing mass?

A. moon, earth, Mars, sun, Jupiter
B. moon, Mars, earth, Jupiter, sun
C. Mars, earth, moon, Jupiter, sun
D. moon, Jupiter, Mars, earth, sun
E. moon, earth, Jupiter, Mars, sun

10. Explorer 7 is a U.S. satellite in an elliptical orbit in which its distance from the center of the earth varies between 4150 and 5500 miles. Compared to the speed at a distance of 5500 miles, its speed at a distance of 4150 miles is

A. greater, in the ratio 4150 to 1.
B. greater, in the ratio 5500 to 4150.
C. the same.
D. smaller, in the ratio 4150 to 5500.
E. smaller, in the ratio 1 to 5500.

11. ALL EXCEPT ONE of the following were arguments used by followers of Copernicus to defend his heliocentric theory. Which one is the exception?

A. A rotating earth is no more likely to break up than a much larger rotating celestial sphere.
B. Lenses change what one sees and, therefore, telescopic evidence may be distorted.
C. It is a simpler, more harmonious system and, therefore, more pleasing to the divine architect.
D. Friction drags the atmosphere along with the rotating earth; therefore clouds and birds are not left behind.
E. The stars are at too great a distance to show a parallax.

Select answers to questions 12 and 13 from the following list.

A. Ptolemy
B. Galileo
C. Kepler
D. Tycho Brahe
E. Newton

12. He demonstrated that the observed planetary motions were consistent with general principles that described all motion everywhere in the universe.

13. His major contributions to astronomy were his accurate measurements.

14. Opponents of Copernicus gave many arguments in support of the Ptolemaic system. ALL EXCEPT ONE of the following support the Ptolemaic system. Which one is the exception?

A. It predicted positions of the bodies of the solar system with fair accuracy.
B. It explained why the fixed stars showed no stellar parallax.
C. It was in accordance with the ideas of "natural motion" and "natural place."
D. It was based on what they sensed: that the earth is motionless and the sun, planets and stars are moving.
E. It explained how comets' orbits could come close to the sun.

15. ALL EXCEPT ONE of the following statements are true. Which is the exception?

A. The earth moves fastest when it is nearest to the sun.
B. The earth's orbit lies in a plane which passes through the sun.
C. A line drawn from the sun to the earth sweeps over the same area from March 21 to March 23 as it does from December 21 to December 23.
D. The sun is at the exact center of the earth's orbit.
E. The earth's orbit around the sun is an ellipse.

16. ALL EXCEPT ONE of the following are correct statements about a satellite in an elliptical orbit around the earth. Which is the exception?

A. One focus of its elliptical orbit is at the center of the earth.
B. Its orbit lies on a plane which passes through the center of the earth.
C. A line drawn from the center of the earth to the satellite sweeps over equal areas in equal time intervals.
D. The satellite moves fastest when it is closest to the earth.
E. There is no net force acting on the satellite.

17. Which of the following is evidence that supports the universality of Newton's law of gravitation?

A. Pairs of stars have been observed that move around each other in accordance with Kepler's laws.
B. A few stars have moved from the positions given for them in Ptolemy's catalogue of stars.
C. Stellar parallax has been observed for several thousand stars.
D. Eclipses of the sun do not occur at every new moon.
E. A calendar reform was needed in the sixteenth century to keep months and seasons in agreement.

18. If the planets were to be listed in order of increasing mean distance from the sun (i.e. Mercury, Venus, . .Pluto), that order would necessarily be the same as listing the planets in order of increasing

A. period of revolution around the sun.
B. period of rotation around their axes.
C. eccentricity of orbit around the sun.
D. size of the planet.
E. brightness of the planet in the sky.

19. Kepler's three laws of planetary motion were

A. almost self-evident from Tycho Brahe's data of Mars' orbit.
B. little used in Newton's development of a general law of universal gravitation.
C. developed only after Kepler took imaginative steps from the available data.
D. widely discussed early in the sixteenth century.
E. used by Copernicus in deriving his heliocentric hypothesis.

20. Heliocentric models of the solar system explain retrograde motion of planets by means of

A. the differences between the rates of motion of the earth and the planets along their orbits.
B. the daily rotation of the earth.
C. combination of the sun's motion northward on the ecliptic and the planets' revolution around the sun.
D. changes in the speed of planets as their distance from the sun changes.
E. corrections to the inaccurate measurements of the ancient astronomers.

Test C

21. The following men made significant contributions to our present understanding of planetary motion.

1. Copernicus
2. Newton
3. Kepler

If the names of these men were arranged in the order of their contributions starting with the earliest first, they would be

A. 1, 2, 3.
B. 2, 3, 1.
C. 3, 1, 2.
D. 1, 3, 2.
E. 2, 1, 3.

22. What is the acceleration due to gravity of a meteor at two earth radii from the center of the earth? Assume the acceleration due to gravity at one earth radius from the center of the earth is 10 meters/second^2.

A. 2.5 m/sec^2
B. 5 m/sec^2
C. 7.07 m/sec^2
D. 10 m/sec^2
E. 20 m/sec^2

23. Which of the following <u>can</u> be represented by a model of the solar system in which the sun revolves around the earth?

1. Each day the sun rises in the east and sets in the west.
2. During the night the stars appear to move about the North Celestial Pole.
3. Eclipses of the sun sometimes occur.

A. 1 and 2 only
B. 2 and 3 only
C. 1 and 3 only
D. 1, 2 and 3
E. none of the above

24. A simple geocentric model with uniform motion about the center of circular orbits explains only one of the following observations. Which one is it?

A. The sun moves slower in the summer than in the winter.
B. The moon shows phases with a period of one month.
C. The planets vary in speed at different points in their orbits.
D. The size and duration of Mars' retrograde motion is not the same at successive occurrences.
E. The planets move with different speeds against the stars at different points of their orbits.

25. Two sacks, each containing 10 oranges of equal mass, are hung four meters apart. Which one of the following would double the gravitational force that one sack of oranges exerts on the other sack?

A. adding 20 oranges of the same mass, 10 to each sack
B. adding 10 oranges of the same mass, 5 to each sack
C. adding 10 oranges of the same mass, to one sack only
D. moving 5 oranges from one sack to another
E. moving 10 oranges from one sack to another

26. Two baseballs are supported at a distance of four meters from each other. If they were moved, at what distance would the gravitational force between them be approximately one-fourth its previous value?

A. 1 meter
B. 2 meters
C. 6 meters
D. 8 meters
E. 16 meters

27. Which one of the following posed no serious difficulties for the Platonic view of heavenly perfection?

A. the new star discovered in 1572
B. the rough appearance of the moon's surface
C. the four satellites of Jupiter
D. sunspots
E. the observed motion of the stars

28. Which ONE of the following statements was not an observation supporting the ancient idea that there is a fundamental difference between the substance of the heavenly bodies and the substance of the earth.

A. Heavenly bodies moved along a regular path whereas earth bound objects moved in an irregular fashion.
B. The heavens seemed perfect whereas the earth did not.
C. The material of the heavenly bodies seemed eternal and unchanging whereas earthly matter was constantly changing.
D. Events in the heavens could not generally be predicted whereas those on earth could be.
E. Heavenly bodies seemed to move without forces whereas a force was required to keep an object in motion on the earth.

Test C

29. To Ptolemy ALL EXCEPT ONE of the following statements were part of the solution to Plato's problem of accounting for the motions of the planets. Which one is the exception?

A. Planetary paths must be composed of circles or combinations of circles.
B. Planets must move relative to the stars.
C. The sun must stand still
D. The stars must move in paths composed of circles.
E. The moon must be nearest the earth.

30. A space probe that missed its target went into orbit around the sun at a mean distance 9 times as great as the earth's. On the basis of Kepler's third law, the period of the space probe is approximately

A. 3 years.
B. 9 years.
C. 27 years.
D. 54 years.
E. 81 years.

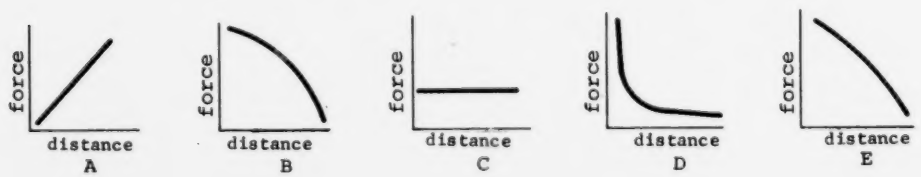
31. If the earth's mass were twice as great as it is, its period of revolution about the sun (assuming it stayed in the same orbit) would be

A. increased by a factor of 4.
B. increased by a factor of 2.
C. hardly changed at all.
D. decreased by a factor of 2.
E. decreased by a factor of 4.

32. A theory predicts a result which is contrary to common sense. We should

A. reject the theory since we must rely on common sense.
B. devise an experiment to test the predicted result.
C. disregard common sense because it is of no value in a scientific study.
D. revise the theory to produce a compromise between the theory and common sense.
E. revise common sense to agree with the new theory.

33. A space ship travels at a constant speed directly away from the earth. Which of the following graphs shows how the force of gravity exerted by the earth on the space ship changes with the distance from the earth?



34. Scientists usually publish their findings in journals which are then distributed throughout the world. One reason they do not try to keep their discoveries secret is that

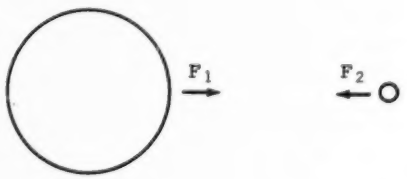
A. few discoveries have any economic or military importance.
B. scientists are not concerned with political or economic affairs.
C. someone would soon give the secret away anyway.
D. scientists want to let others know what they have done.

35. Newton's law of universal gravitation was distinctive in the history of physics because it was the first

A. explanation of the cause of gravity.
B. demonstration that the same equations can be used to describe motion on the earth and in the heavens.
C. accurate mathematical description of the planetary orbits.
D. demonstration that Kepler's laws and Copernicus' hypotheses were alternate explanations of the same observations.
E. use of algebra to describe physical phenomena.

36. If F_1 is the magnitude of the force exerted on the sun by the earth and F_2 is the magnitude of the force exerted on the earth by the sun, then

A. F_1 is much greater than F_2.
B. F_1 is slightly greater than F_2.
C. F_1 is equal to F_2.
D. F_1 is slightly less than F_2.
E. F_1 is much less than F_2.



37. Assume that the following measurements were made on three planets revolving about a star. (Planets listed in order of discovery.)

Planet	Orbital Period	Mass
Alpha	14 earth years	10 earth masses
Beta	188 earth years	17 earth masses
Gamma	50 earth years	1/2 earth mass

On the basis of Kepler's laws of planetary motion, these planets could be arranged in order of their increasing distance from the star. If the planets were listed in sequence, starting with the planet nearest the star, they would be arranged

A. Alpha, Beta, Gamma.
B. Beta, Gamma, Alpha.
C. Gamma, Alpha, Beta.
D. Beta, Alpha, Gamma.
E. Alpha, Gamma, Beta.

Test C

38. One of Newton's contributions to astronomy was his description of

A. the algebraic equations of *ellipses and other conic sections*.
B. the forces that produce the elliptical orbits of the planets.
C. the distances to the planets.
D. the geometry of the elliptical orbits of the planets.
E. the theory of light.

39. Assume the earth suddenly became one-half its original diameter, but that its mass was unchanged. Under this assumption, the strength of the earth's gravitational pull on the moon would be

A. four times as great.
B. twice as great.
C. the same.
D. one-half as great.
E. one-fourth as great.

40. ALL EXCEPT ONE of the following state aspects of Kepler's work. Which one is the exception?

A. He emphasized the mathematical regularities of planetary motion.
B. He recognized the value of precise observations.
C. He gave a mathematical description of the cause of planetary motion.
D. He helped to perfect the theory of the solar system in which the planets move around the sun.
E. He recognized that a planet's path was not a circle.

Test D

Directions

This test consists of 8 questions in two groups. Answer only FOUR of the five questions in Group One, and only TWO of the three questions in Group Two. Spend about 5 minutes on each of the questions from Group One, and 10 minutes on each of the questions from Group Two.

NOTE:
The numerical values of some physical constants and equations that may be useful in this test are given below.

Physical Constants:

Acceleration of gravity on surface of earth (approximate value to be used in this test) $a_g = 10$ meters/sec^2

Radius of the earth $R_E = 6{,}400{,}000$ meters

Mass of the earth $m_E = 5.96 \times 10^{24}$ kg

Equations:

$$F_{grav} = G\frac{m_1 m_2}{R^2} \qquad v = \frac{2\pi R}{T}$$

$$T^2 = ka^3 \qquad a = \frac{v^2}{R}$$

$$T^2 = \left[\frac{4\pi^2}{Gm}\right] R^3 \qquad \frac{m_1}{m_2} = \left[\frac{R_1}{R_2}\right]^3 \left[\frac{T_2}{T_1}\right]^2$$

Test D

Group One

Answer only FOUR of the five questions in this group.

1. Indicate briefly the major contributions to astronomy of

   a) Kepler
   b) Newton

2. Briefly describe what is meant by "Newton's great synthesis."

3. State and discuss briefly one hypothesis used by both Ptolemy and Copernicus, but completely abandoned by Kepler in his theory of planetary motion.

4. According to Kepler's "harmonic law" the period of revolution of a planet is related to the mean radius of its orbit by the equation $T^2 = ka^3$. The mean radius of the orbit of Saturn around the sun is 9 Astronomical Units. What is its period of revolution in years? (Show your calculations.)

5. Draw a graph of the earth's gravitational attraction on a 10-kilogram mass versus its distance from the center of the earth. Let R equal the earth's radius. Make entries at distances R, 2R, 3R and 4R.

Group Two

Answer only TWO of the three questions in this group. Spend about ten minutes on each question.

6. a) What is retrograde motion?
   b) Explain retrograde motion (with the aid of a diagram) using either a heliocentric or a geocentric model of the solar system.

7. In order to develop an equation for the gravitational force F_{grav} between the sun and a planet, Newton had to determine the way in which the force of gravitation depends upon the mass of the sun M_s and the mass of the planet M_p. Among the possible hypotheses are the following proportionalities:

A. $F_{grav} \propto (M_s + M_p)$

B. $F_{grav} \propto (M_s\ M_p)$

C. $F_{grav} \propto (M_s/M_p)$

   a) Which of the above is the relationship Newton chose?
   b) Pick one of the other two options and give a reasonable argument for rejecting it.

8. Two criteria for an adequate theory are:

   a) the theory that it be based upon simple assumptions.
   b) that it be in agreement with experimental observations.

Did the Ptolemaic (earth-centered) theory of planetary motion of 150 A.D. satisfy these criteria? Explain your answer.